

## Toward a new outlook on primate learning and behavior: complex learning and emergent processes in comparative perspective<sup>1</sup>

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**Abstract:** Primate research of the 20th century has established the validity of Darwin's postulation of psychological as well as biological continuity between humans and other primates, notably the great apes. Its data make clear that Descartes' view of animals as unfeeling "beast-machines" is invalid and should be discarded. Traditional behavioristic frameworks – that emphasize the concepts of stimulus, response, and reinforcement and an "empty-organism" psychology – are in need of major revisions. Revised frameworks should incorporate the fact that, in contrast to the lifeless databases of the "hard" sciences, the database of psychology entails properties novel to life and its attendant phenomena. The contributions of research this century, achieved by field and laboratory researchers from around the world, have been substantial – indeed revolutionary. It is time to celebrate the progress of our field, to anticipate its significance, and to emphasize conservation of primates in their natural habitats.

**Key words:** learning, language, intelligence, emergent processes.

The literature of recent decades has revealed a remarkably close relationship between humans and the great apes (*Pan*, *Gorilla*, and *Pongo*; see Napier & Napier, 1994; Sarich & Wilson, 1968; Tuttle, 1986). Darwin's (1859, 1871) postulation of psychological as well as biological continuity between animals and humans has been confirmed (Domjan, 1993, p. 391). It is particularly important that this continuity is advanced in the Western world, where the Cartesian (Descartes, 1637, reprinted 1956) view that animals have no sensibilities – that animals are "beast-machines," lacking reason, consciousness, affect, intelligence, and language – has been so influential. According to this philosophy, humans, but not animals, were held

to have souls, which enabled them to think and reason. Accordingly, humans could be held accountable for their deeds. Human pain was viewed as God's punishment for wrongdoings. But because animals, *sans* souls, could not be held accountable for their "bad" behavior, God was believed to protect them from feeling pain under any condition. True, they might act as though they suffered, but that was only appearance. The experience of pain was reserved for humans!

Western behaviorists have held that neither humans nor animals have "agency of action." They do not enter actively into the determination of their behavior. Although the Gestalt psychologists of Europe allowed for

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cognition (that is, knowing, the creative capacity to reorganize perceptions and past learning to generate new solutions to problems), the behaviorists looked to the reinforcement histories of animals and to stimuli of the external and internal environments to understand behavior (see Mackintosh, 1994, for a review). This research philosophy emulated that of physics and chemistry – the “hard” sciences – that enjoyed substantially more respect and prestige than psychology. It was as though psychologists attributed the success of the other sciences to their refutation of *life* variables, and thus rejected life dimensions from their own theory and methods to achieve “standing” for their science. In doing so, they failed to acknowledge a major error: although the sources of data for physics and chemistry are *lifeless*, the very foundation of psychology’s subject material, behavior, is generated *only* by life – the human and animal life of our world. Thus, the data for psychology must be qualitatively different from the data of physics and chemistry.

If the philosophy of the early and even contemporary “empty-organism” psychology had been limited to the building of a science of behavior, its impact might have been appropriately limited. Regrettably, however, philosophical concepts are readily reified. They become “real” and generalize inappropriately to other domains. Thus, the empty-organism philosophy of behaviorism appears to have become viewed as valid by societies. In turn, it might well have served to justify insensitive practices, attitudes, and policies within societies, not only regarding animals, but for people and the environment as well.

Behaviorism gained sway during the early and mid-1900s as scientific, prestigious, valid, and sufficient to the end of understanding *all* behavior. Mackintosh (1994, p. 10) observed, for example, that despite Tolman’s several strong differences and arguments with the psychology of Hull and Thorndike, he did agree with them that “everything important in psychology (except ... super-ego ... and matters that involve society and words) can be investigated in essence through the continued experimental and theoretical analysis of the

determinants of rat behavior at a choice point in a maze.” Mackintosh also suggested that Tolman likely could have counted on the support of Skinner if lever pressing were included with choice behavior in mazes.

Mackintosh (1994) reaffirmed his own view that it is now hard to believe that anyone would have argued seriously that such research would be of general value. Personally, we are now incredulous that such a view would ever have been seriously advanced. (The first author recalls his own days in graduate school and how impressed he was by the perspectives of Hull, Tolman, Skinner, and Guthrie; but times change – and they should.)

Frankly, we are now advocating that behavioral primatologists re-examine all of the constructs and concepts of behaviorism that were generated during the first three-quarters of this century. We should do so because the perspectives, arguments, and conclusions of current years have advanced well beyond the perspectives of behaviorism, especially the postulate that reinforcement is necessary for all learning, and thus for most if not all behavior.

More progress has been made than we frequently recognize. It is time to take stock and celebrate the accomplishments of recent decades that have altered or extended the perspectives of historic behaviorism. Although behavior will remain the basic focus of analysis, we need to re-examine even our most basic tenets and terms.

### The null hypothesis

To begin this effort, let us consider a statistical point – one that is essentially a general misuse of the null hypothesis. The null hypothesis would postulate that “no difference” exists between the psychological processes of humans and animals. That hypothesis should be rejected only when one’s observations indicate that “a real difference” exists – one not attributable to chance. By contrast, both we and our audiences tend to *begin* with the conclusion that real differences exist between the psychology of humans and animals and that the onus is upon the researcher to prove that such is

not the case! Indeed, we often assume that these differences are so profound as to make it impossible to compare the behavior of humans to animals using similar methodologies, or to extrapolate from animals to humans. (Parker, in press, advances relevant perspectives.)

It bears noting that Darwin's postulate of psychological as well as biological continuity between animals and humans was an appropriate use of the null hypothesis, though he did not know it by that name. He did not, of course, argue for complete identity of process, and neither should anyone. By definition, other primates are not identical to us; but because of the very close genetic similarity between apes and humans (>98% shared DNA between *Pan* and *Homo*; also see Andrews & Martin, 1987; Sarich, 1983; Sibley & Alquist, 1987), there are grounds to anticipate important similarities in their psychology as well as in their neurobiology.

### Rejection of the "beast-machine"

Recent behavioral research with primates has produced abundant evidence against the Cartesian beast-machine concept and for Darwin's postulations of continuity (Gibson & Ingold, 1993). Researchers from around the world, working in the field and the laboratory, have contributed overwhelming evidence of primates' capabilities for complex and malleable systems of communication, symbolizing capacities, rule learning, number learning, counting, drawing, and even language. This achievement has been possible because of the spirit of mutual respect that scientists have had for one another's data. Behavioral research from Japan (for example, Itani, 1979; Kano, 1989, 1992; Kuroda, 1989; Matsuzawa, 1985, 1990; Nishida, 1989, 1990) has contributed significantly to the formulation of the perspective that we advance in this paper.

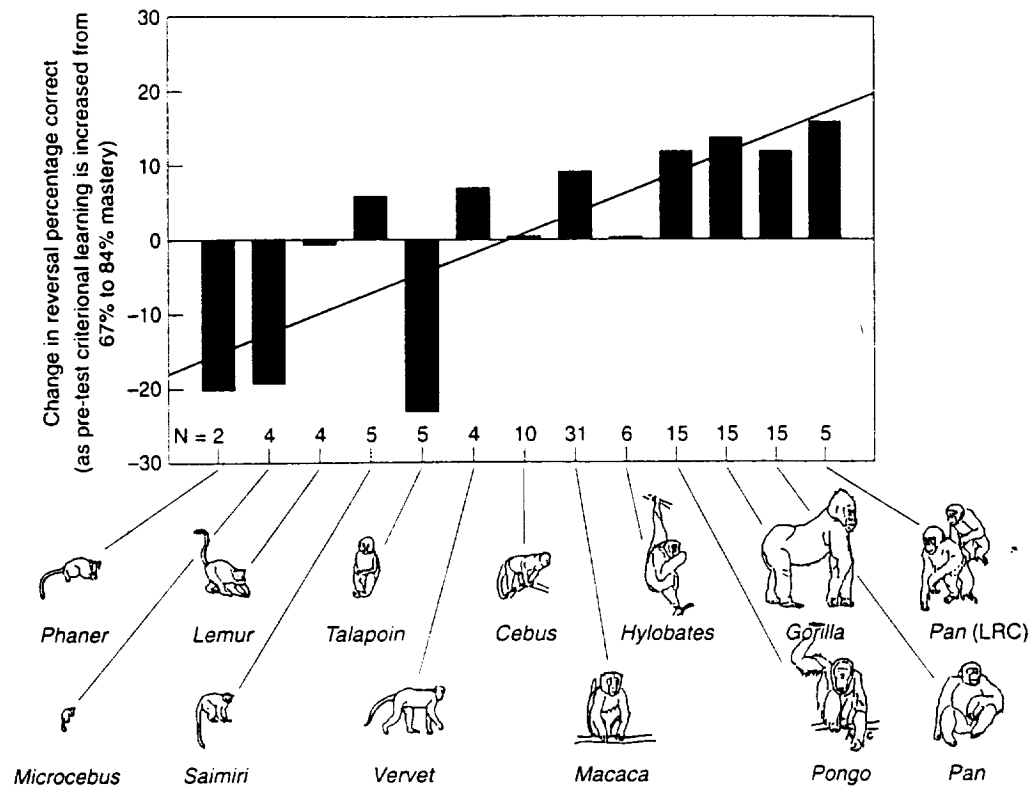
In contrast to the learning and behavioral psychologists who studied animals in laboratories in the United States during the heyday of behaviorism, behavioral primatologists have made revolutionary advances because they have eschewed the "empty organism" or "empty

box" perspective. They know that species differ multidimensionally and that genetic differences create psychological differences both in the simpler and in the more complex forms of behavior. They see clearly that there are emergent dimensions to behavior that are reflections of brain and cognitive evolutionary processes. They know that primates are, in measure, reflections of their early rearing and environments and that early environment is crucial to the development of normal, socially competent primates. They do not have to be persuaded that the roots of human biobehavioral competence are traceable to our nonhuman primate relatives and that, to the degree that there is a relationship between them and between them and us, there are similarities both in appearance and in behavior.

### Brain, learning, and transfer of learning

Allow us to discuss now some of the Language Research Center's interests in the parameters of human intelligence that can be traced to our nearest living relatives – the great and lesser apes, the monkeys of the New and Old Worlds, and the prosimians. A long-standing tactic for this study posited a relationship between *transfer of learning* and *brain complexity*. Transfer of learning was assessed through the use of the transfer index (TI), a procedure designed for equitable assessments of primates' complex learning processes. Its design attenuates artifactual differences between species' learning and performance that might be due to differences in their size, manual dexterity, attentiveness, and so on.

Research with 121 primate subjects of several species relates their transfer-of-learning skills to their brain complexity. Prior to test, specific amounts or levels of learning were established using procedures that brought subjects to two levels of accuracy in a series of visual discrimination learning problems – 67% and 84% choices correct (see Rumbaugh & Pate, 1984; Rumbaugh, in press, for details). Figure 1 portrays the change in test performance (percentage responses correct) as the



**Figure 1.** The enhancement of transfer-of-learning in relation to brain complexity of primate ( $N = 121$ ) is portrayed. The ranking of brain complexity here offered correlates very highly both with the "extra" neurons (.96) and tissue (.98) afforded these species beyond that predicted by brain-body allometry (see text). The vertical axis quantifies the *change* in the percentage of responses that are correct as a result of the pre-transfer test learning criterion being increased from 67% to 84% correct. Each point on the baseline is for a particular species, except for the one (far right) that is for five language-competent chimpanzees and bonobos of the Language Research Center. Their enhanced performance is probably the result of the enrichment afforded by their research participation and their language skills. (See Acknowledgments for contributions of unpublished data from others. See Cooper (1980) and De Lillo and Visalberghi (1994) as sources for data on *Phaner*, *Microcebus*, and *Capuchin*. Other unpublished capuchin data were contributed by Drs. William Hopkins and Stephen Suomi, Laboratory for Comparative Ethology, the National Institutes of Health.)

amount of pre-test learning was increased from the 67% to the 84% level. It should be noted that as the amount of learning was increased, the prosimians and smaller monkeys generally tended to do worse on discrimination reversal tests. Increased learning handicapped their performance on transfer tests. By contrast, the great apes and even the larger monkeys with more complex brains did better on their transfer tests as the degree of pre-test learning was

increased. Thus, an important qualitative shift across species was documented in transfer skills and the amount of learning that they were permitted to acquire prior to tests of transfer.

There was a high and positive rank order correlation (Spearman  $r = .79$ ) between our rank ordering of brain complexity and ability to transfer. This ranking by brain complexity subsequently was found to correlate highly with Jerison's (personal communication) estimation

of the "extra brain volume" (.96) and his calculations of "extra neurons" (.98). "Extra" here is in reference to the amount of extra brain and extra neurons afforded by encephalization processes that have enlarged primate brains beyond that predicted by allometric relationships between brain and body sizes for mammals. Average body weights and brain weights per species correlated highly with each other (.96); body weight correlated highly with transfer-of-learning proficiency (.88); and brain weight per species also correlated highly with transfer skills (.84). Thus, for primates, a large body means a disproportionately large brain and hence a greater quantity of "extra" neurons, which, in turn, correlate highly with the values obtained from the y-axis of Figure 1 (extra brain volume,  $r = .82$ ; and extra neurons,  $r = .79$ ). If elaboration of the frontal lobes was made possible by reason of this "extra" volume, transfer of training could be enhanced through the inhibition of responses that otherwise would produce perseveration and errors.

Jerison's (1985) encephalization coefficient, relating brain weight to body weight, is only generally correlated with the body weights of the primate species used here, and thus did not correlate significantly with transfer skills. Both the diminutive squirrel monkey (*Saimiri*) and talapoin have higher encephalization coefficients than does the massive gorilla, while they are substantially below the gorilla in their complex learning and transfer skills.

In the early 1970s, the first author reported evidence for qualitative differences in the learning processes of nonhuman primates (see Rumbaugh & Pate, 1984). A current interpretation of those data holds that there is a general emergence of relational learning (rather than simpler, associative stimulus-response learning) as the primate brain evolves in size and complexity. This change, along with the qualitative shift from negative to positive transfer, as measured by methods relevant to Figure 1, documents how emergent processes of adaptation are afforded by brain evolution. It was because of these kinds of data that, when the LANA Project (Rumbaugh, 1977) was

initiated by the first author in 1971, an ape – not a monkey – was selected as a subject.

### Apes and language: a brief review

The readers of this journal are probably familiar with the accomplishments of researchers with respect to issues of apes and language potential. Notwithstanding, a brief review of selected results from our own studies will support the perspective advanced in this paper.

Project work with Lana (*Pan troglodytes*; see Rumbaugh, 1977) afforded the following results. (1) It proved the efficacy of using lexigram-embossed, computer-monitored keys that we have now used for the past 24 years, in that Lana readily learned about 250 word-lexigrams (i.e., geometric patterns) on her keyboard and how to sequence them in accordance with the rules of grammar that had been programmed into the computer that controlled the operations of her keyboard and various vending devices. (2) It provided evidence of Lana's ability to build upon and to make novel use of stock sentences, which she first learned through operant training methods, to solve new problems. (3) It demonstrated that Lana's performance in cross-modal perceptual tasks was facilitated when the objects had names.

In spite of Lana's several remarkable achievements, she did not provide an answer to the question of fundamental importance – what is language? In response to obvious need for us to pursue our own answer to this question, the second author of this paper initiated Project Sherman and Austin (*P. troglodytes*; see Savage-Rumbaugh, 1986). Sherman and Austin's data contributed to the answering of this question.

(1) Words have several distinct functions that support symbolic communication. The skills entailed in making a request are different from those entailed in the naming or labeling of things.

(2) Words are more than the associations of symbols with things and events. For a symbol to be a word, there must be *comprehension* both when the symbol is used and when it is received. Comprehension is not necessarily instated by the skills of either requesting or naming.

(3) Comprehension seemingly is based on long-term coordination of social behavior through the use of symbols. Through working on a variety of tasks, such as those that entailed joint attention and complying with one another's requests for specific foods and tools, Sherman and Austin became adept at understanding lexigrams as well as at requesting and naming items.

(4) As Sherman and Austin mastered their tasks, they extended their skills to new functions. Perhaps the most impressive was their formulation of *statements* about what they were about to do and/or what food or drink they would retrieve from an array just surveyed in another room.

(5) Consistent with the framework that we advance here, emergent operations afforded Sherman and Austin new and impressive competencies, ones neither specifically the target of training nor anticipated by the research team.

(6) The categorization skills of Sherman and Austin indicated that they had a basic capacity for semantics. These skills were manifest in an experiment where, in final test, they correctly classified all but one of 17 word-lexigrams (that represented various foods and tools) through use of two lexigrams, one standing for *tool* and the other for *food*. In this situation Sherman and Austin used their word-lexigrams, not to request or name items, but only to categorize them. Their skill in so doing clearly indicates the representational dimensions of semantics that the symbols had for Sherman and Austin.

More recent findings have emerged that even we would not have thought possible 10 years ago (Savage-Rumbaugh, Murphy, Sevcik, Brakke, Williams, & Rumbaugh, 1993). Apes can learn, without formal training, to understand the semantics and even the meaning of human speech at a level that compares favorably with that of a 2–3-year-old child. The ape's comprehension of spoken words is assessed by its competence in selecting the appropriate referent for single words that it hears in controlled experimental situations. Its comprehension of meaning is assessed by its capacity to carry out novel sentences of request that it hears.

Kanzi's (*Pan paniscus*) comprehension of over 600 novel sentences of request was very comparable to Alia's, a 2½-year-old child. Both carried out the requests without assistance for approximately 70% of the sentences. Kanzi was exposed to language training between the ages of 6 and 30 months, while present during his adoptive mother's (Matata) daily training sessions. Matata never benefitted substantially from that training. (Matata had been brought to the Yerkes Regional Primate Research Center, Emory University, from the wilds of Zaire for reproductive biomedical research in the early 1970s; perhaps it was because of her having been reared in the ways of the forest that she never succeeded in language acquisition.)

Matata's failure, however, in no way impeded Kanzi in his spontaneous language acquisition. His skills were manifested when Matata was sent to the Yerkes Field Station for breeding. It was only then, when he was about 2½ years old, that his language training program was to begin. That program was never implemented, however. It was unnecessary. Kanzi already knew what Matata had been intended to learn. In sum:

(1) Kanzi's language skills appeared spontaneously, without formal training. The course of Kanzi's language development was, first, *comprehension* of speech and the use of lexigrams by others. His skills of production emerged naturally from this language base and involved the use of both lexigrams and gestures (Greenfield & Savage-Rumbaugh, 1991, 1993).

(2) His comprehension skills included the ability to understand novel sentences of request as well as single words.

(3) It is suggested that the bonobo's capacity for human language is latent and that in the wild it provides for other complex capacities, that are perhaps relevant to language in ways that are not yet clear to us – or that perhaps *are* language. Savage-Rumbaugh, Williams, Furuichi, and Kano (in press) have reported that the bonobos of Wamba, Zaire, use vegetation to mark, so as to inform other bonobos who follow, the path they have taken at points where their trails divide.

### Language acquisition and the logic structure of the environment

The course of language acquisition (Bates, 1993) for the normal human child is, first, comprehension (i.e., understanding), then production (i.e., speech). Most of the basics of language are acquired spontaneously, that is, without formal training.

Kanzi is the first ape to have acquired language competence in this manner. He first came to understand speech and then to generate his "utterances" through use of his word-lexigrams and gestures (Greenfield & Savage-Rumbaugh, 1991, 1993). Kanzi's opportunities for the spontaneous acquisition of language came not through formal training, but through his daily observations of the language instruction given to his mother.

Thus, we argue that it was his extensive opportunities to observe the reliable, predictable, meaningful, consistent, and communicative patterns of "language instruction" offered his mother that afforded him "spontaneous" language acquisition. A summary way of capturing this conclusion is to say:

- (1) that it was through Kanzi's reliable access to the patterned experiences afforded by the *logic structure* of his environment (e.g., the speech of the experimenters and their use of word-lexigrams on a keyboard that structured his mother's instructional sessions) that
- (2) he perceptually *discerned* and *learned* the relationships between symbols and events that provided for him the basic processes and competencies with language.

Kanzi's observational learning of complex abilities also extends to the making of stone tools (Toth, Schick, Savage-Rumbaugh, Sevcik, & Rumbaugh, 1993). Given the opportunity to observe a professional flint-knapper, Kanzi learned of stone tools – of their use, value, and means of production. He makes stone tools and does so with good sense. He assesses his flint chips for sharpness and, quite appropriately, makes larger chips to cut thick cables of rope and smaller ones to cut thin ones.

### *Co-rearing of a bonobo and a chimpanzee*

Because all of our common chimpanzees (*P. troglodytes*) had required formal training for the instatement of their language skills and had manifested only minimal speech comprehension, a co-rearing study of a bonobo (Panbanisha) and a common chimpanzee (Panzee) was undertaken to determine whether Kanzi's achievement was specific to his species (Savage-Rumbaugh, 1991; Savage-Rumbaugh, Brakke, & Hutchins, 1992; Savage-Rumbaugh & Lewin, 1994).

By the age of 2½ years, both subjects came to understand single words and the meanings of lexigrams for both comprehension and production, though Panbanisha's skills were substantially greater than Panzee's. Thus the bonobo probably excels in language skills relative to the common chimpanzee: for both species, however, it is in the logic structure of the infants' environments that their complex abilities, competencies, and dimensions of intelligence and expression are optimally formed. Their formation is behaviorally "silent" (e.g., not observable) in that their expression might not occur until the age of 2 years or older. The language skills both of Panbanisha and Panzee were highlighted by speech comprehension, an ability never established via the training protocols of our prior work with chimpanzees.

### *Early impoverished environmental effects*

Early environmental stimulation can have general facilitating effects upon development. It is in the *logic structure* of the early environment, however, that the basic vectors of cognitive competence are formed. An important corollary of this important principle is that the specific effects of the logic structure probably depend on brain size and complexity. Early environment is probably much more critical to the great apes than to monkeys and prosimians with regard to the likelihood of specific emergent processes (e.g., language and speech comprehension) being formed quietly by the infant's reliable interaction with the logic structures of its environment.

This point is made even clearer when it is recalled that studies in the 1960s and 1970s

documented that chimpanzees subjected to impoverished rearing even during only the first two years of infancy are both socially and cognitively deficient for complex learning and the transfer of learning some 12 years later, as adults (Davenport, Rogers, & Rumbaugh, 1973).

Appropriate language-structured rearing instated in the ape what none of the earlier efforts designed to teach apes specific language skills through use of tutorials could, namely the ability to comprehend speech and its syntax. That style of rearing also served to instate spontaneously appearing productive language skills that approximate those of a 1½-year-old normal child.

### Rhesus monkeys in comparative perspective

At this juncture, we must direct our discussion to monkeys, for a new perspective on their competencies has been established through the development of the Language Research Center's Computerized Test System (LRC-CTS; Rumbaugh, Richardson, Washburn, Savage-Rumbaugh, & Hopkins, 1989; Richardson, Washburn, Hopkins, Savage-Rumbaugh, & Rumbaugh, 1990; Washburn, Hopkins, & Rumbaugh, 1989). This system has not only been a successful automation of the Wisconsin General Test Apparatus (Washburn et al., 1989), but it also has afforded us and dozens of other laboratories around the world an economical system for research into questions limited only by the researcher's vision and imagination.

Notwithstanding the judgment that monkeys have an order of smartness or intelligence that is substantially below that of the apes, at least the larger ones are impressive. Research at the Language Research Center has defined their precision use of a joystick in a battery of complex tasks designed to measure learning, memory, vigilance, eye-hand coordination, planning, relative value judgments, and so on. For the purposes of this paper it suffices to list the following:

(1) Rhesus' performance on the transfer index is impressively high and, coupled with the number of trials which they work each day,

accurately predicts training success on the comprehensive battery of tasks referenced above (Washburn & Rumbaugh, 1994).

(2) Rhesus shift their object-discrimination learning from stimulus-response associative to more advanced relational processes as a function of protracted experience in the LRC-CTS (Washburn & Rumbaugh, 1992a).

(3) Rhesus work better when they can choose tasks on which to work than they do when those same tasks are otherwise assigned, and they prefer to work for rewards rather than to receive them passively, "for free" (Washburn & Rumbaugh, 1992b).

(4) Rhesus are "super-learners." They readily learned the relative values of the numeral set 0–9, even though they did not have to choose the larger number in order to get pellets (Washburn & Rumbaugh, 1991). Even on novel test trials, on which certain pairings of numerals were presented for the first time, they reliably picked the number with the greater pellet value.

(5) Handedness by rhesus in joystick manipulation is strongly established. Right-handed monkeys tend to be more facile learners than left-handed monkeys (Hopkins, Washburn, Berke, & Williams, 1992).

(6) Rhesus monkeys manifest many characteristics of selective attention similar to those of humans. For instance, they are sensitive to the Stroop-like interference when quantities, between which they are to differentiate, comprise Arabic numbers (Washburn, 1994).

(7) Rhesus are *predictor-operators* in tasks where they must anticipate the collision courses of two images, one of which is under their direct control (Washburn & Rumbaugh, 1992c). They "shoot" at where a target will be and "chase" to head targets off at points where they will be by the time the image under the monkey's control can intercept it.

(8) Rhesus monkeys, like humans, can indicate when they are uncertain in making choices and do so generally at times that are appropriate (Schull, Smith, Washburn, & Shields, 1994).

(9) The vast majority of independent variables studied to date in our laboratory have the same effects upon rhesus performance as

they do in task performance by humans (e.g., Washburn, Hopkins, & Rumbaugh, 1990).

### A new perspective on basic concepts

It is now clear that Descartes was wrong. Descartes' beast-machine model of animals has been discredited and should no longer influence the thinking and values of our societies. We also conclude that the well known American advocates of behaviorism were more than just incomplete in their psychologies – they were quite possibly wrong in significant and fundamental ways. It is timely that we consider revisions of some of our most basic concepts. To that end, we offer the following perspective of: learning, reinforcement, stimuli, responses, and continua and emergent processes.

#### Learning

Research methods served to emphasize, and even to equate, learning with a *change* in behavior. Changes in behavior are necessary for learning to be inferred, but learning of even complex forms can be established in the absence of overt, observable motor responses. Evidence for this argument includes the fact that language acquisition by apes reared in a language-structured environment is *silent* in that there might be no bases for inferring speech and lexigram comprehension until they are about 2 years of age or even older.

Collaborative research by W. K. Richardson, D. A. Washburn and D. M. Rumbaugh with rhesus monkeys provides important findings in support of this view of learning. Initial training consisted of having the subject use a foot to manipulate a joystick to solve an interactive video-formatted task. The task required that the subject move the cursor to make it collide with an erratically moving target. Once this skill was acquired and the monkey was allowed for the *first* time to use its hand to operate the joystick, it did substantially *better* than it had ever done with its foot. Its learning was not in the use of the muscle groups to perform the task; rather, its learning was about the demands of the task and how those demands

might be met – initially with the foot, but later more competently with its hand. Here, learning is not properly viewed as “responses with the foot”. Rather, learning is more accurately viewed as “about the task” (in this context, “direct the cursor into contact with the moving target”). Reinforcement of specific muscle groups was irrelevant.

We suspect that, guided by biological proclivities and constraints, organisms tend to perceive relationships, especially new ones, between all kinds of events, objects, foods, barriers, and so on (Hinde & Stevenson-Hinde, 1973; Ristau, 1991; Roitblat, Bever, & Terrace, 1984). Organisms are always exposed to stimuli, including the previously mentioned items, across time. In particular, primates (and notably the great apes and humans) have brains that probably excel at processes of ordering, relating, and categorizing things that they sense and things that they perceive. This orientation directs learning to the perception of relationships rather than to the reinforcement of specific responses, except to the degree that there is a relationship defined between the execution of a specific response and the procurement of a specific reinforcement. From this perspective, “reinforcers” become resources and are managed from a “resource management” perspective. (Pay checks sustain our efforts but only rarely shape or declare highly specific behaviors.)

Thus, learning may be “latent” (in place, but not evidenced) or it may be “silent” for long periods. But, nonetheless, it can be there. When the requisite conditions for its recall and application are encountered, the learning is called upon and becomes a valuable tool to help with the continuing effort to achieve optimal adaptation.

#### Reinforcement

Reinforcement generally has been viewed as something that strengthens the probability of responses and as a requisite for learning. Indeed, the emphasis on reinforcement has been so great that the ready conclusion is at hand that for every observed behavior there must be a reinforcement history.

Admittedly, reinforcement is generally salient and can have a major impact upon behavior in that it is generally necessary if a given behavior is to be sustained. Complex language competence can be instated basically by allowing apes to observe events in a language-structured rearing environment, where specific motor responses by them are *not* entailed because of their motoric immaturity. Therefore, "reinforcement" is perhaps more completely defined as an element to be related perceptually by the infants to other events than it is to something which inherently strengthens foregoing responses.

We should explore the wisdom of viewing "reinforcement" as information or as a resource that can be accessed when needed – if the requisite behaviors are utilized. Learning and behavior can be viewed, then, as means whereby organisms access the resources, the reinforcements of their environments in the struggle to achieve optimal levels of adaptation, given the time and energy budgets which can be expended.

#### *Stimuli*

Stimuli have been generally defined as changes in the strength of some energy source, be it internal or external. There is no doubt that such changes tend to attract attention and to generate responses. In addition, however, some stimuli are defined or instated *by the subject*. Thus, whenever it is clear that a "stimulus" is inherently a *relationship* between things (whether they be stimuli, responses, reinforcers, or other), we should remember that it was the subject's psychology and neurobiology – not reinforcement *per se* – that induced or inferred the relationship to which behavior is now being directed.

#### *Responses*

Responses have been generally viewed as rather specific motor patterns. It is now clear that they also can be far more general in that they can be "task-completion" designed. They also might be primarily perceptual and cognitive rather than motoric. They perhaps are more accurately viewed as the natural products

of a complex brain, notably those of primates, to organize *adaptive* action patterns given the options and constraints of the present context as modulated by both past and present experience. The organization of adaptive action patterns can be based even on the observation of various relationships between the actions of others and ensuing events. And it should be noted that this form of learning is one of patterns of goal-directed behaviors, not of specific responses.

#### *Continua and emergent processes*

The complexities of life are the expressions of continua in multiple interactions. The evolution of brain in size and complexity and in relation to the body's characteristics; the evolution of perceptual systems; the evolution of refined motor systems; the protraction of periods of pregnancy and development; modulations on social structures compelled by environmental resources and energy budgets which address the various challenges of staying alive; and other dimensions of evolution beyond the scope of this discussion all provide for the *emergence* of new processes, new abilities, new behaviors and even new psychologies (Rumbaugh, Washburn, & Hillix, in press). No psychology built on data of a single species in a constrained study situation, be it a maze, an operant chamber, or other problem situation, can be adequate to our need to cope with the changes referenced.

### Summary

In contrast to physics and chemistry, the data obtained by behavioral primatologists and by psychologists come *exclusively* from entities that are distinguished by the fact that they have *life*. New perspectives of behavior must incorporate this fact and, in some manner, develop a language system which takes into account the probability that all animal forms, and notably the primates, have

- (1) a sense of *being* that pertains to many dimensions of their lives

- (2) a *knowledge-based assessment* of their environment; and
- (3) an *assessment of their capabilities* and what it is that they might be able to do (Rumbaugh & Savage-Rumbaugh, 1994).

These sources of information and estimation are used to achieve, as far as possible, successful adaptation and reproduction.

Behavioral primatologists have reason to proceed with confidence that Darwin was correct in his postulations of *psychological* as well as biological continuities between animals and humans. Accordingly, if there is a compelling reason for us to accept the value of a process or construct for understanding human behavior, we should not rule out the probability that traces thereof can be discerned at the non-human level (Bates, Thal, & Marchman, 1991; Bruner, 1972; Domjan, 1993; Goodall, 1986; King, 1994; Koehler, 1925; Krasnegor, Rumbaugh, Schiefelbusch, & Studdert-Kennedy, 1991; Menzel, 1979; Roitblat, Herman, & Nachtigall, 1993; Tuttle, 1986). To do so is not to call for either an anthropocentric or an anthropomorphic framework or approach. Rather it is to assert a logical implication of *continuities* in psychological processes until data compel us to accept, for a specific operation, otherwise.

The future will likely reveal that much of the perspective advanced herein for primates holds, in measure, for many other forms of life as well. One certainly must be intrigued with that possibility, given all that behavioral primatologists have learned – most of which could not have been imagined even a few decades ago.

## References

- Andrews, P., & Martin, L. (1987). Cladistic relationships of extant and fossil hominoids. *Journal of Human Evolution*, *16*, 101–108.
- Bates, E. (1993). Comprehension and production in early language environment: A commentary on Savage-Rumbaugh, Murphy, Sevcik, Brakke, Williams, and Rumbaugh. "Language comprehension in ape and child." *Monographs of the Society for Research in Child Development*, *58*(3–4), 222–242.
- Bates, E., Thal, D., & Marchman, V. (1991). Symbols and syntax: A Darwinian approach to language development. In N. A. Krasnegor, D. M. Rumbaugh, R. L. Schiefelbusch, & M. Studdert-Kennedy (Eds.), *Biological and behavioral determinants of language development*, pp. 29–65. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Bruner, J. (1972). Nature and uses of immaturity. *American Psychologist*, *27*, 687–708.
- Cooper, H. M. (1980). Ecological correlates of visual learning in nocturnal prosimians. In P. Charles-Dominique, H. M. Cooper, A. Hladik, C. M. Hladik, E. Pages, G. F. Pariente, A. Petter-Rousseaux, J. J. Petter, & A. Schilling (Eds.), *Nocturnal Malagasy primates* (pp. 191–203). New York: Academic Press.
- Darwin, C. (1859). *The origin of species*. London: Murray.
- Darwin, C. (1871). *The descent of man – and selection in relation to sex*. London: Murray.
- Davenport, R. K., Rogers, C. W., & Rumbaugh, D. M. (1973). Long-term cognitive deficits in chimpanzees associated with early impoverished rearing. *Developmental Psychology*, *9*, 343–347.
- De Lillo, C., & Visalberghi, E. (1994). Transfer index and mediational learning in the tufted-capuchin. *International Journal of Primatology*, *15*, 275–288.
- Descartes, R. (1956). *Discourse on method*. New York: Liberal Arts Press. (Originally published, 1637.)
- Domjan, M. (1993). *The principles of learning and behavior*. Pacific Grove, CA: Brooks/Cole Publishers.
- Gibson, K. R., & Ingold, T. (1993). *Tools, language, and cognition in human evolution*. New York: Cambridge Press.
- Goodall, J. (1986). *The chimpanzees of Gombe: patterns of behavior*. Cambridge, MA: Belknap Press.
- Greenfield, P., & Savage-Rumbaugh, E. S. (1991). Imitation, grammatical development, and the invention of protogrammar by an ape. In N. A. Krasnegor, D. M. Rumbaugh, R. L. Schiefelbusch & M. Studdert-Kennedy (Eds.), *Biological and behavioral determinants of language development* (pp. 235–258). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Greenfield, P., & Savage-Rumbaugh, E. S. (1993). Comparing communicative competence in child and chimpanzee: The pragmatics of repetition. *Journal of Child Language*, *20*, 1–26.
- Hinde, R. A., & Stevenson-Hinde, J. (Eds.) (1973). *Constraints on learning*. London: Academic Press.
- Hopkins, W. D., Washburn, D. A., Berke, L., & Williams, M. (1992). Behavioral asymmetries of psychomotor performance in rhesus monkey:

- A dissociation between hand preference and skill. *Journal of Comparative Psychology*, **106**, 392-397.
- Itani, J. (1979). Distribution and adaptation of chimpanzees in an arid area. In D. A. Hamburg & E. R. McCown (Eds.), *The great apes* (pp. 55-71). Menlo Park, CA: Benjamin/Cummings.
- Jerison, H. J. (1985). On the evolution of mind. In D. A. Oakley (Ed.), *Brain and mind* (pp. 1-31). London: Methuen.
- Kano, T. (1989). The sexual behavior of pygmy chimpanzees. In P. G. Heltne & L. A. Marquardt (Eds.), *Understanding chimpanzees* (pp. 176-183). Cambridge, MA: Harvard University Press.
- Kano, T. (1992). *The last ape: Behavior and ecology of pygmy chimpanzees*. Stanford, CA: Stanford University Press.
- King, B. J. (1994). *The information continuum* (p. 167). Sante Fe, NM: School of American Research Press.
- Koehler, W. (1925). *The mentality of apes*. New York: Harcourt Brace.
- Krasnegor, N. A., Rumbaugh, D. M., Schiefelbusch, R. L., & Studdert-Kennedy, A. M. (Eds.) (1991). *Biological and behavioral determinants of language development*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Kuroda, S. (1989). Developmental retardation and behavioral characteristics of pygmy chimpanzees. In P. G. Heltne & L. A. Marquardt (Eds.), *Understanding chimpanzees* (pp. 178-193). Cambridge, MA: Harvard University Press.
- Mackintosh, N. J. (Ed.) (1994). *Animal behavioral and cognition* (p. 379). New York: Academic Press.
- Matsuzawa, T. (1985). Use of numbers by a chimpanzee. *Nature*, **315**, 57-59.
- Matsuzawa, T. (1990). *The perceptual world of a chimpanzee*. Project number: 63510057. Inuyama, Aichi, 484 Japan.
- Menzel, E. W., Jr. (1979). Communications of object-locations in a one-acre field. In D. A. Hamburg & E. R. McCown (Eds.), *The great apes* (pp. 359-371). Menlo Park, CA: Benjamin/Cummings.
- Napier, J. R., & Napier, P. H. (1994). *The natural history of primates*. Cambridge, MA: MIT Press.
- Nishida, T. (1989). Social interactions between resident and immigrant female chimpanzees. In P. G. Heltne & L. A. Marquardt (Eds.), *Understanding chimpanzees* (pp. 68-89). Cambridge, MA: Harvard University Press.
- Nishida, T. (1990). *The chimpanzees of the Mahale Mountains: Sexual and life history strategies*. Tokyo: University of Tokyo Press.
- Parker, S. (in press). Anthropomorphism is the null hypothesis and recapitulation is the bogey man in comparative developmental evolutionary studies. In R. Mitchell, N. Thompson & H. L. Miles (Eds.), *Anthropomorphism, animals, and anecdotes*. Albany, NY: State University of New York Press.
- Richardson, W. K., Washburn, D. A., Hopkins, W. D., Savage-Rumbaugh, E. S., & Rumbaugh, D. M. (1990). The NASA/LRC computerized test system. *Behaviour Research Methods, Instruments and Computers*, **22**(2), 127-131.
- Ristau, C. (1991). *Cognitive ethology*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Roitblat, H. L., Bever, T., & Terrace, H. (1984). *Animal cognition*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Roitblat, H. L., Herman, L. M., & Nachtigall, P. E. (1993). *Language and communication: comparative perspectives*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Rumbaugh, D. M. (Ed.) (1977). *Language learning by a chimpanzee: The LANA project*. New York: Academic Press.
- Rumbaugh, D. M. (in press). Competence, cortex and animal models: A comparative primate perspective. In N. Krasnegor, R. Lyon, & P. Goldman-Rakic (Eds.), *Development of the prefrontal cortex: Evolution, neurobiology, and behavior*. Baltimore, MD: Paul H. Brookes.
- Rumbaugh, D. M., & Pate, J. (1984). The evolution of primate cognition: A comparative perspective. In H. L. Roitblat, T. G. Bever & H. S. Terrace (Eds.), *Animal cognition* (pp. 569-587). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Rumbaugh, D. M., & Savage-Rumbaugh (1994). Learning, prediction, and control with an eye to the future. In M. M. Haith, J. B. Benson, R. J. Roberts, Jr. & B. F. Pennington (Eds.), *The development of future-oriented processes* (pp. 119-138). Chicago: University of Chicago Press.
- Rumbaugh, D. M., Richardson, W. K., Washburn, D. A., Savage-Rumbaugh, E. S., & Hopkins, W. D. (1989). Rhesus monkeys (*Macaca mulatta*), video tasks, and implications for stimulus-response spatial contiguity. *Journal of Comparative Psychology*, **103**, 32-38.
- Rumbaugh, D. M., Washburn, D. A., & W. A. Hillix (in press). Respondents, operants, and emergents: Toward an integrated perspective on behavior. In K. Pribram (Ed.), *Learning as a self-organizing process*. Hillsdale, NJ: Lawrence Erlbaum Associates.

- Sarich, V. M. (1983). Retrospective on hominoid macromolecular systematics. In R. L. Ciochon & R. S. Corruccini (Eds.), *New interpretations of ape and human ancestry* (pp. 137-150). New York: Plenum.
- Sarich, V. M., & Wilson, A. C. (1968). Immunological time scale for hominid evolution. *Science*, **158**, 1200-1202.
- Savage-Rumbaugh, E. S. (1986). *Ape language: From conditioned response to symbol*. New York: Columbia University Press.
- Savage-Rumbaugh, E. S. (1991). Language learning in the bonobo: how and why they learn. In N. A. Krasnegor, D. M. Rumbaugh, R. L. Schiefelbusch & M. Studdert-Kennedy (Eds.), *Biological and behavioral determinants of language development* (pp. 209-233). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Savage-Rumbaugh, E. S., & Lewin, R. (1994). *Kanzi: At the brink of the human mind*. New York: John Wiley.
- Savage-Rumbaugh, E. S., Brakke, K. E., & Hutchins, S. S. (1992). Linguistic development: Contrasts between co-reared *Pan troglodytes* and *Pan paniscus*. In T. Nishida, W. C. McGrew, P. Marler, M. Pickford & F. B. M. de Waal (Eds.), *Topics in primatology* (pp. 51-66). Tokyo: University of Tokyo Press.
- Savage-Rumbaugh, E. S., Murphy, J., Sevcik, R. A., Brakke, K. E., Williams, S., & Rumbaugh, D. M. (1993). Language comprehension in ape and child. *Monographs of the Society for Research in Child Development*, Serial No. 233, **58**(3-4), 1-22.
- Savage-Rumbaugh, E. S., Williams, S. L., Furuichi, T., & Kano, T. (in press). *Paniscus branches out*. In B. McGrew, L. Marchant, & T. Nishida (Eds.), *Great ape societies*. London: Cambridge University Press.
- Schull, J., Smith, J. D., Washburn, D. A., & Shields, W. E. (1994). Uncertainty monitoring in rhesus monkeys. In J. R. Anderson, J. J. Roeder, B. Thierry, & N. Herrenschmidt (Eds.), *Current primatology (Volume III): Behavioural neuroscience, physiology and reproduction* (pp. 101-119). Strasbourg: Université Louis Pasteur.
- Sibley, C. G., & Ahlquist, J. E. (1987). DNA hybridization evidence of hominoid phylogeny: Results from an expanded data set. *Journal of Molecular Evolution*, **26**, 99-121.
- Toth, N., Schick, K. D., Savage-Rumbaugh, E. S., Sevcik, R. A., & Rumbaugh, D. M. (1993). *Pan* the tool-maker: Investigations into the stone tool-making and tool-using capabilities of a bonobo (*Pan paniscus*). *Journal of Archaeological Science*, **20**, 81-91.
- Tuttle, R. H. (1986). *Apes of the world*. Park Ridge, NJ: Noyes Publications.
- Washburn, D. A. (1994). Stroop-like effects for monkeys and humans: processing speed or strength of association? *Psychological Science*, **5**, 375-379.
- Washburn, D. A., & Rumbaugh, D. M. (1991). Ordinal judgments of numerical symbols by macaques (*Macaca mulatta*). *Psychological Science*, **2**, 190-193.
- Washburn, D. A., & Rumbaugh, D. M. (1992a). The learning skills of rhesus revisited. *International Journal of Primatology*, **12**, 377-388.
- Washburn, D. A., & Rumbaugh, D. M. (1992b). Investigations of rhesus monkey video-task performance: Evidence for enrichment. *Contemporary Topics in Laboratory Animal Science*, **31**, 6-10.
- Washburn, D. A., & Rumbaugh, D. M. (1992c). Comparative assessment of psychomotor performance: Target prediction by humans and macaques (*Macaca mulatta*). *Journal of Experimental Psychology: General*, **121**, 305-312.
- Washburn, D. A., & Rumbaugh, D. M. (1994). Training rhesus monkeys (*Macaca mulatta*) using the Computerized Test System. In J. R. Anderson, J. J. Roeder, B. Thierry & N. Herrenschmidt (Eds.), *Current primatology (Volume III): Behavioural neuroscience, physiology and reproduction* (pp. 77-83). Strasbourg: Université Louis Pasteur.
- Washburn, D. A., Hopkins, W. D., & Rumbaugh, D. M. (1989). Automation of learning-set testing: The video-task paradigm. *Behavior Research Methods, Instruments, and Computers*, **21**, 281-284.
- Washburn, D. A., Hopkins, W. D., & Rumbaugh, D. M. (1990). The effects of competition upon video-task performance in monkeys (*Macaca mulatta*). *Journal of Comparative Psychology*, **104**(2), 115-121.

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